## Information for Handover Management in Heterogeneous Networks: data representation, languages and integrated platforms

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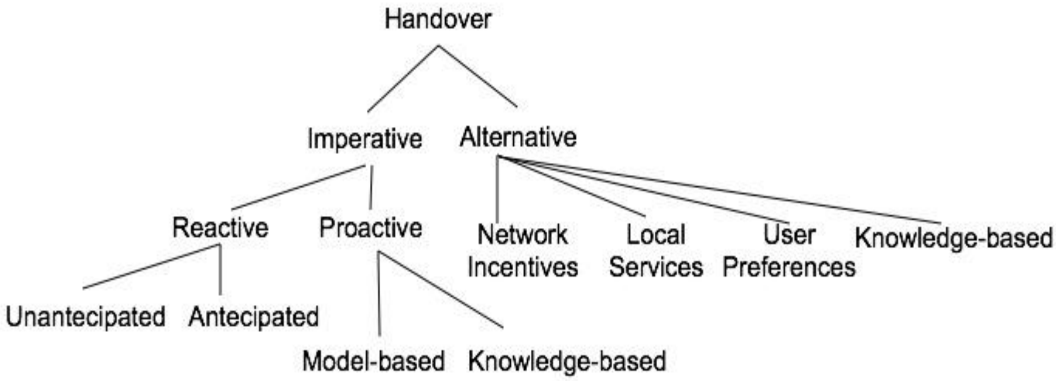
***Abstract.*** *Due to the convergence of radio, television, telephony and Internet areas, the mobility of users, the ubiquity of services, and the development of new technologies to unify access provision, the interaction between providers and users will be required for access on demand in heterogeneous environments. This interaction should allow, in addition to seamless handovers, the negotiation based on technical requirements and user's desires during handover decision processes. The central part of the information being exchanged between the access provider's attachment points and user's devices should be a uniform and common structure that models the handover management information, in terms of what the information represents their semantic meanings and relationships. This work presents a set of ontologies, for this purpose, employed during handover decision processes, in integrated networking platforms for access on demand. A case study is presented, which demonstrates how a service could be integrated in two different platforms for such environment.*

**Keywords:** access on demand, handover management, heterogeneous networks, integrated networking platform.

## 1 Introduction

In the future, wireless communication networks will consist of a diversity of wireless networks with different capabilities, with wireless wide area networks and short-range networks as the main components for cellular mobile and local broadband access, respectively (Frank et al., 2007). The other kinds of networks will be designed to complement the access provision in a ubiquitous environment for communication services, where the users have smooth mobility. The mobile users will require access on demand from different providers, making their agreements on the go. From the providers' side, a minimum information exchange will be required to guarantee the service continuity in a seamless handover.

The handover is pivotal for the smooth mobility in ubiquitous environments; it is the process of transferring an ongoing call or data session from one network attachment point to another (Vidales, 2005). It can be classified based on the reasons under which it occurs - Figure 1. An imperative handover occur due to technological reasons only. It is done because some technical analysis determined that is good. Some parameters being checked are signal strength,




coverage and the quality-of-service offered by a new network.

**Figure 1 -** Handover classification (adapted from Mapp et al., 2009)

Imperative handovers are divided into proactive and reactive handovers. The reactive handover is executed to react to an absence of communication conditions (low or no radio signal). Reactive handovers can be split into anticipated and unanticipated handovers. Anticipated handovers describe the situation where there are more attachment points available to which the mobile node may hand over. With unanticipated handover the mobile is going out of range and there is no other attachment point to hand over. On the other hand, the proactive handover is done to anticipate the negotiation to a new channel connection when it can be predicted, then the mobile seeks to know the conditions of the networks at a given location before it reaches that point. This enables it to choose beforehand when it should hand over. Proactive handovers can themselves be divided into two groups. The first is knowledge-based handover in which the mobile studies the coverage maps of wireless networks in its neighbourhood and then decides when to do the handover. The other one is a mathematical model based on propagation models; the location, speed and direction of the mobile device can be used to determine when a handover should occur.

In complement to imperative handovers, alternative handovers can occur due to reasons other than technical issues (Bansal et al., 2004; Moreira et al., 2007). The factors to performance an alternative handovers include a preference for a given network based on user preferences, network incentives (price, bonus, etc), local services and knowledge-based. The knowledge-based classification in alternative handovers is related to information that complements the coverage maps of wireless networks, for example, historical information about quality-of-experience (QoE) of users on such networks.

The handover process decision is an issue of great complexity which increases with the number of parameters to be treated. The access on demand in heterogeneous networks requires new platforms to deal with this complexity (Vanni et al., 2006). This work is based on two platforms that take a different approach to the network-controlled model used by the cellular networks, the handovers should be client-based yielding the empowerment to user devices of which attachment point to hand over (Patanapongpibul and Mapp, 2003). Both platforms are designed to support access on demand, but one platform focus on imperative handover and the other platform focus on alternative handover. Some observations bellow are relevant to this work as well.

In regard to global provision, it is noticed in large cities that the huge amount of antennas for cellular networks and of access points for local networks has already created a ubiquitous environment in terms of radio signal for networking. A step forward is to turn it ubiquitous for communication services through agreements on the go to accesses on demand. In order to achieve it, Y-Comm (Y-COMM, 2010; Mapp et al., 2007) is a new platform for ubiquitous networking by the seamless operation of heterogeneous wireless networks, which does the brokerage between mobile users and providers for access on demand during the imperative handover decision processes.

On the other hand, regarding to local provision, it is observed that local networks not only provide access to the Internet, but eventually offer local services related to the local business/event. The mobile user should aggregate great value to the quality of experience (Vanni et al., 2005) using a local network where the mobile device is moving and sensing. Besides the local services, the user should be attracted by network incentives and positive historical user experience information generated by themselves or other ones. With this purpose, SOHand (Yokoyama et al., 2008; SOHAND, 2010) is a novel approach for heterogeneous networking platforms, which exploits alternative handovers in local networks during user mobility.

The aim of this work is to create mechanisms to mitigate misunderstandings by formally describing terminological concepts and their relationships that characterize the information used by the handover decision processes in integrated access provision platforms. These mechanisms are supported by ontologies which normalize concepts and describe semantic relationships. Such solution should reduce the learning time and the misunderstanding of definitions by the entities (users, providers, brokers and third parties) involved on access on demand, despite of the heterogeneity in terms of technology, business model and domain.

The rest of paper is structured as follows: Section 2 describes the Y-Comm platform while Section 3 describes the SOHand platform. Section 4 summarizes what is an ontology, while session 5 shows how ontologies can help to reduce the learning time and the misunderstanding in both platforms. The paper ends with section 6, about conclusions and future work.

## 2 Y-Comm Frameworks: an integrated platform for global communication

Y-Comm is a new platform to support global networking provided by independent access providers using heterogeneous technologies at distinct management domains. It uses two frameworks split in layers. The first is called Peripheral Framework and deals with operations and functions on the mobile node for vertical handover based on technical reasons. The other framework is called Core Framework and shows the functionality required in the core network to support global networking. A brief explanation of Y-Comm platform is now described considering only the layers related to imperative handover processes. A detailed explanation is found in (Y-COMM, 2010).

## 2.1 Peripheral Framework for Imperative Handover

The first layer is the hardware platform layer, it is used to classify all relevant wireless technologies. Hence different wireless technologies which are characterized by the electromagnetic spectrum, MAC and modulation techniques make up this layer. The next one is the network abstraction layer, it provides a common interface to manage and control all the wireless networks. These first two layers for both frameworks are similar in functionality. For the Peripheral framework, the hardware platform and the network abstraction layer run on the mobile node; for the Core framework, the two layers run on the base station. On both, their goal is to control the functions of various wireless network technologies residing on the mobile node or the base station. The vertical handover layer, above the network abstraction layer, acquires the resources for handover, does the handover signaling to the layers bellow it, does the context transfer for the new attachment point and reinitialize packet reception. Finally, the policy management layer deals with imperative handover; this layer decides whether, when and why handover should occur. This is done by looking at various parameters related to handover such as signal strength and policies to decide both the time and place for doing the handover; demanding it to vertical handover layer.

## 2.2 The Core Framework

As previously mentioned, the first two layers of the Core Framework are engaged in controlling base station operations. The third layer is called the Reconfiguration Layer and it is a control plane to manage key infrastructure such as routers, switches, and other mobile network infrastructure using programmable networking techniques (Patanapongpibul and Mapp, 2003).
The Network Management layer is a management plane that is used to control networking operations in the core. This layer can divide the core into a number of networks which are managed into an integrated fashion. It also gathers information on these networks in a location-specific manner such that it can inform the policy management layer on mobile nodes about peripheral networks at its location – neighborhood. High-level functions of this layer can create, merge and partition networks built on an extended hardware platform.

## 2.3 Strategies for Imperative Handover Management

Imperative Handover Management in Y-Comm requires technical information analysis to determine why the handover must be done (e.g. quality-of-service parameters), when it will be executed (e.g. location, position and time parameters), and which one is the new attachment point (e.g. identification, technology and authentication parameters).

This technical information comes from different sources (sensors, third parties, applications) that execute triggers in response to certain changes (events) in technical status. These sources usually have distinct representation for the parameters and it can cause misunderstandings – some examples at table 1. Moreover, the entities involved in the handover decision process should improve their participation if they have a clear comprehension of what each concept and relationship mean.

**Table 1.** Examples of displacement conditions in imperative handover and distinct interpretation

| *Displacement conditions* | *Some measures or references* |
|---|---|
| Signal strength | dBmV/m, dbμV/m, dBm |
| Data rate | bit/s, kbit/s, Mbit/s, ... |
| Throughput | bit/s, kbit/s, Mbit/s, ... |
| Delay | Seconds or fractions of seconds |
| Loss | Transmission BER, Information BER, data loss |
| Technology | 802.11a/b/g/n or Wi-Fi or WLAN, EDGE/GPRS or UMTS or 3G, 802.15 or Bluetooth or WPAN, 802.16 or WiMax or WMAN, etc. |
| Attachment point | Antenna, base station, access point |

Other useful information for imperative handover decision process and controlling has to be mapped. As a means to attempt to determine when and where handover should occur, it is necessary to have knowledge of networks in the local area where the mobile is located. In addition, in order to perform the handover, it is necessary to know the topology of these local networks. So networks wanting to be part of Y-Comm need to register their networks and their topology with the network management layer running locally in the core network. This is independently administered so that different network operators need not have to reveal their networks and topology to each other.

A mechanism to register the topology data in the correct form and to hide the sensitive business information is claimed.

## 3 SOHand: an integrated platform for local communication

SOHand is an platform that proposes a novel access model in ubiquitous environments keeping in mind the emerging technologies for integrated platforms and the convergence areas over IP (Internet Protocol) – multimedia, telecommunication, Digital TV and Internet (Yokoyama et al., 2008; SOHAND, 2010).

User devices in SOHand are able to gather information to define, e.g., the user context, network context and neighborhood context. The contextual information is used to enrich the user experience during the utilization of a network.

### 3.1 SOHAND Modules

A brief explanation about SOHand platform is done following Figure 3.

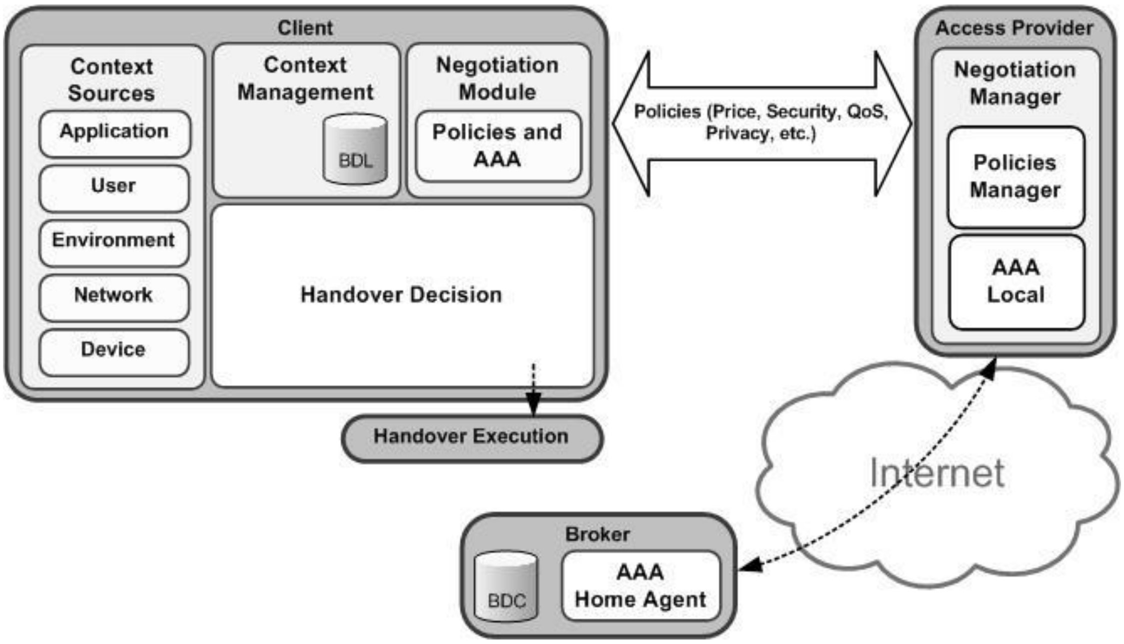



**Figure 3 -** SOHand modules

SOHand is composed by the client side, the provider side and a broker. The client side has context sources (CS). Each CS supplies information which can be gathered by the user device. The Context Manager (CM) is responsible for (i) processing the contextual information from the CS; (ii) recording the contextual information in a Local Database (LDB); and (iii) monitoring the current networking state, the user device resources and the user preferences in use. The Negotiation Module (NM) runs services supplied by the networking environment to negotiate the access with providers based on defined policies and contextual information. The Handover Manager (HM) makes the alternative handover decisions based on user preferences (non-technical desires) as pricing, security, trust and provider bonuses.

The provider side has a Negotiation Manager (NM) composed by two parts: (1) the Policies Manager (PM) that informs the policies for access related to the user position; and (2) The Local AAA that, after the negotiation, performs the authentication, the authorization, and the Accounting. Finally, the Broker is the entity that makes available the information for negotiation from different providers and centralizes it all in an AAA Home. This information support the negotiation between users and providers, and between providers. Users that are not clients of a chosen provider, will be verified by the provider at the AAA Home. These mechanisms permit the access on demand maximizing the matches for user desires (preferences and incentives). For example, the technical conditions from provider A can be better than from provider B, but the user should hand over to provider B just because it offers more incentives as low pricing, local service (traffic information) and bonuses. In addition, the Broker has the historical contextual information informed by users in a Centralized Database (CDB). These information should be used by providers and by users. Providers should improve their services, create new ones or to offer personalized services through the analysis of such database content. Users, in turn, should look at the past choices of other users and the quality-of-experience they had, in order to support their own decisions.

### 3.2 Strategies for Alternative Handover Management

Alternative Handover Management in SOHand requires information analysis of reasons beyond technical issues. It determines why the handover must be done (e.g. Network incentives, services and user preferences), when it will be executed (e.g. location, position and time), and which one is the new attachment point (e.g. identification, technology and authentication parameters).

This information comes from different sources (sensors, third parties, applications) that gather networking information and user behavior during a connection, and incentives/services from the whereabouts (Moreira et al., 2007). As mention before, these sources usually have distinct representation for each information and it can cause misunderstandings – table 2 shows some examples. Additionally, SOHand offers contextual and historical information to be exploited by users, sophisticating their choices, and by providers, improving their services.

**Table 2.** Examples of displacement conditions in alternative handover and distinct interpretation

| *Displacement conditions* | *Some measures or references* |
|---|---|
| Price | Per minute, per day, per data transmission |
| Traffic Information (service) | Location, route, vehicle |
| User preference | Preferable network ID in some contexts (location, day of week, activity, application in use, ...) |
| Security | Cryptography, authentication, privacy |
| Trust | Communities, historical information, footprint data |
| Quality-of-experience | Networking rating in some subjects (service, security, trust, bonus, ...) |

## 4 Ontologies - An overview

An ontology is an explicit specification of a conceptualization (Gruber, 1993). Its main goal is to mitigate misunderstandings by formally describing terminological concepts and their relationships that characterize a domain (Lacy, 2005). For instance, suppose that several access providers contain information about 3G base stations. If these providers share the same ontology of the terms and relations, their software agents can extract and aggregate information about their network topology based on 3G base stations at an Y-Comm broker for global networking provision.

Traditionally, semantics have been hard-coded within software. Ontology turns it explicit; it means documenting concepts with modeling primitives and semantic relationships, which in turn make expressive statements about the domain model. Semantics are needed to assist in interpretation during information sharing in heterogeneous IT systems. For instance, the providers sharing their topology with Y-Comm must know, for each type of technology used by the base station, the information they have to send, what it means, its structure and relations.

Common components of ontologies to structure and describe knowledge are:

*Classes.* The ontological class concept is related to the object class concept in object-oriented programming (OOP) and tables from Relational Databases Management Systems (RDBMS). For instance, the class “Base_station” is the group of all individuals with similar characteristics defined by the ontology.

*Individuals***.** Individuals are basic objects that can be enclosed into class sets; they represent class object instances in the described domain. For example, the individual “XPTO” is a base station (an object in the real world) with attributes defined by the class “base_station”.

*Properties.* The ontological property concept associates attribute/value pairs with instances. Examples of properties of a “base_station” instance are “technology”, “location”, “QoS”, and “name”.

*Relationships.* Ways in which classes, properties and individuals related to one another. The most important inter-concept relationships include “is an instance of” (individual to class), “has value for” (individual to property), and restrictions (between class and properties). For example: individual “XPTO” *is instance of* class “basestation”, and *has value “*3G” *for* property “technology”.

*Restrictions.* Formally stated descriptions of what must be true in order for some assertion to be accepted as input. For example, class “base_station” *has restriction* on property “technology” to range {3G, WiFi, WiMax}.

*Rules. S*tatements in the form antecedent --> consequent sentence that describe the logical inferences that can be drawn from an assertion in a particular form.

*Axioms. S*tatements that may or may not be true (including rules) in a logical form that together comprise the overall theory that the ontology describes in its domain of application. For example, it is an axiom in SOHand ontology that local services are incentives provided by the local networks.

*Events.* Changes on attributes or relations. For example, a new value of “signal strength” or the signal of a new access provider on the neighborhood.

## 5 How ontologies can help to reduce the time-to-deployment and the in Y-Comm and SOHand

The set of ontologies is coded in OWL Language (Lacy, 2005; W3C, 2010; OWL, 2010) as a set of components to explicit the semantic of Y-Comm and SOHand platforms. These components, as described above, are: Classes, Individuals, Properties, Relationships, Restrictions, Rules, Axioms, and Events. The instance data in compliant with the ontology are stored in RDF/XML (RDF, 2010; XML, 2010).

The Y-Comm ontology and SOHand ontology have both two approaches: (a) the description of terminological concepts and their relationships; and (b) the description of the handover process decision.

The first one encompasses classes and relationships of both frameworks' layers in Y-Comm and the modules from the user side and provider side in SOHand. This approach aims to help the development of brokerage system based on the desired platform, describing the managers and their internal interactions.

The second approach maps the external interactions, and it aims to support users, providers and third-parties on the development of services to Y-Comm and SOHand. As examples of services, it was developed the providers' topology description in Y-Comm and the historical quality-of-experience of users (Vanni et al., 2005) in SOHand.

### 5.1 Y-Comm Ontology and SOHand Ontology

Classes and subclasses are defined by the *is-a relation*, for example "Hardware Layer" class *is-a subclass of "*Y-Comm Layer" class. Once the subclass is transitive property, this is useful to define taxonomies of classes, coming from the most general concepts of Y-Comm to the specific ones, reaching individuals like the base station itself.

The *equivalent-to* relation between classes is used to identify a synonymous class, it is useful to show classes which have the same individual members, but may represent different concepts and be subclasses of different classes. For example, "Basestation" class *is equivalent-to* "Hardware Layer" class, these classes represent different concepts, for example the Basestation class should be imported from an ontology dealing with network components, but the classes still have the same members (base station individuals).

The *intersectionOf* relation between classes is used from " Neighborhood Topology" class to "Topology" class, it is coded in OWL in terms of the base stations from different network topology belong to neighborhood topology. Here there is an example of how the neighborhood topology is built on demand, based on which location and range is used at the moment. The reasoned will infer new statements from this relation, for example that some base stations are either *part-of "Neighborhood* Topology" class.

Other important relation used to mitigate misunderstanding is *disjoint-with*. I t is used to distinguish two or multiple classes as having no individuals in common (no overlap). An example is the *disjoint-with* relation between different technologies (3G, WiFi, WiMax). Since it is a symmetric and transitive, it means that if 3G *is disjoint-with* WiFi, and WiFi *is disjoint-with* WiMax, then the inverse is true and 3G *is disjoint-with* WiMax.

There are objects proprieties described that relate one class to another (domain to range) and the inverse proprieties. For example “BasestationManager” *controls* “Basestation” which, in turn, *isControlledBy* “BasestationManager”.

The data properties are similar to object property, the difference is regarding the range, instead of a class, it is a type as string, date, integer, float, and so on. For example, some object properties and data properties for basestation class are: component/resource (hardware and software), technology, QoS, name and location.

The SOHand Ontology has the same benefits mentioned above, as class, subclass, equivalent-to, disjoint-with, and so on. For example, the contextual information is formed by User Context, Application Context, Environment Context, Network Context, Device Context.

### 5.3 The case study: How Y-Comm ontology and SOHand Ontology can be extended and used by a new entity

A third-party application named Wireless Footprinting (WF) (Lopes et al., 2009) has used and extended the Y-Comm ontology and the SOHand ontology. WF supports knowledge-based handovers in both platforms. The information being obtained depends from the ontology being used by the platform. In Y-Comm, the WF collects and maps information about the networks topologies (technology, position, QoS, SSID, etc). In SOHand, the WF is concerned with user quality-of-experience information. In WF, mobile users record information about networks the first time they are encountered and can retrieve and update this information when the mobile node is again traveling in that vicinity. Since different users are using one Wireless Footprinting System (WFS), it is possible to share with others the information about the wireless neighborhood, and this in turn allows user devices to determine when it is the best point to make a handover among available networks.

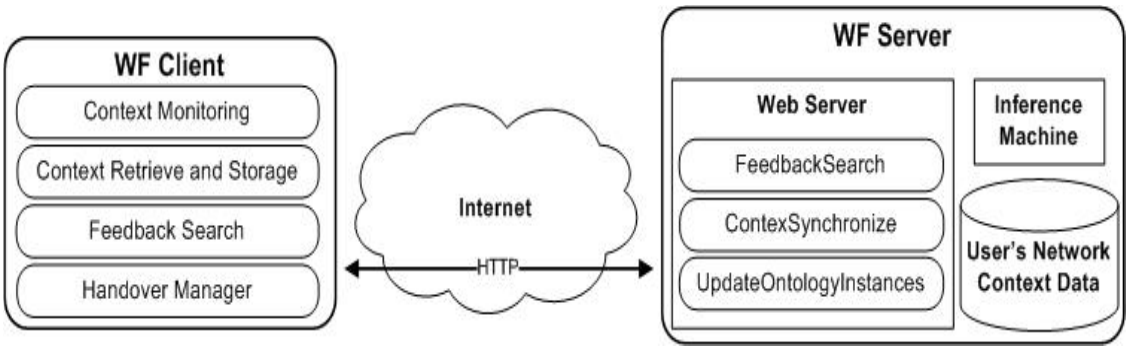



**Figure 4** – WF main services at server and client side

The WF main services are shown on Figure 4 and described below:

1. Context Retrieve and Storage: This service uses the wireless tools in order to retrieve context network data of all wireless networks that the mobile node can reach at a point.
2. Context Monitoring: This module decides when the network context data could be retrieving and stored.

3. Feedback search: Given the geographical coordinates of user's current location the service returns the past experience of other users at the same place.
4. Handover manager: Decides what is the next access point using current network context data and past experience of other users.
5. Context Synchronize: This module is responsible for getting the data at user's device and synchronizes with the server side keeping the consistence.
6. Update ontology instances: Get the data from the data base and generates an OWL file. This procedure is done periodically.

The WF imports and extends the Network Management Layer in the Y-Comm ontology, and the Context Management in SOHand. However, instead of access providers providing information about neighborhood topology, it is the users themselves that are updating the Neighborhood entity of the ontology which is represented by the database on the WFS. So users read parameters for their network interfaces via the interface manager and the GPS (Global Positioning System) sensor manager, and update the neighborhood entity, i.e. the database.

The exchange between the WF Server and the WF client uses XML (XML, 2010), the data are stored in RDF (RDF, 2010) derived from the OWL structures. Finally using the extended ontology for the WFS, the footprint data is obtained from a server in Java programming language (JAVA, 2010). This is done using Jena (JENA, 2010) which is a Java Framework for Building Semantic Web-based applications, with a programming environment for OWL language including a rule-based engine.

## 6. Conclusion and Future work

This paper has presented a novel approach based on ontologies for the normalization of concepts related to handovers in platforms offering brokerage services in heterogeneous networking environments. The ontologies were written in OWL language which can be parsed and understood by software – independent of the programming language. The developed set of ontologies permitted the mapping of displacement conditions in handover decision processes and their distinct interpretation. The advantages of this approach can be applied when users, providers, third-parties and brokers from a different semantic viewpoint are trying to be part of such platforms.

It was addressed in this paper the integration of a third-party named Wireless Footprinting into the two chosen platforms, Y-Comm and SOHand, through the instantiation and extension of the developed ontologies.

In addition to the stated advantages of the ontologies in session 4, it was shown that the OWL language provides additional vocabulary along with a formal semantics, enriching the formalization of the concepts and facilitating the machine interpretability.

As future work, it will be proposed a process to support the collaboration between the parties involved in the development, implementation, deployment and maintenance of the ontologies.

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